and a bottom surface coated by an insulating material, said Schottky metal layer covering said trenches and mesa regions, said insulating material sandwiched between said Schottky metal layer and said sidewalls and bottom surfaces.

A8

56. The diode of claim 1, wherein said barrier potential energy is such that said diode operates as a low forward voltage diode.

57. The diode of claim 55, wherein said diode operates with a forward voltage in the range of 0.1 to 0.3 volts.

REMARKS

Claims

Objections

The examiner objected to claims 2, 3, 6, 15, 19, 20, 22 and 47-49 because of informalities/defects and the claims have been amended to incorporate the examiner's suggested changes. It should be noted that these claim amendments are only "suggested" to improve the form of the claims and they are "non-limiting". Accordingly these amendments do not limit the scope of the claims and are not being made for reasons related to patentability.

Rejections

35 U.S.C 102(b)

The examiner rejected claims 1-5, 7, 8, 14-21, 23, 24, 28 and 43-48 under 35 U.S.C. 102(b) as being anticipated by Mohammad et al. ("Mohammad"; Electronics Letters, March 14, 1996, V32, N6, pages 598-599). Mohammad et al. describes the fabrication and electrical characteristics of nearly ideal Pt-GaN Schottky diodes. The authors investigation and findings focused on GaN based diodes that "are expected to operate at high power levels, high temperatures and in a caustic environment." With high power, high voltage the reverse leakage current is minimized by the barrier potential.

The present application discloses and fully describes a GaN based diode with low forward voltage (V_f) operation, in the range of 0.1 to 0.3 volts. In applicants' GaN Schottky diodes, the barrier height at the metal to semiconductor junction varies depending on the metal used. Using a particular metal, the diodes Schottky barrier height can be lowered resulting in a lower V_f. Mohammad does not disclose, teach or suggest this lower V_f Schottky diode operation or a Schottky metal that would result in this lowered barrier potential. One of the possible reasons that this type of operation has not been previously developed is that it generally results in an undesirable increase in the reverse current leakage (I_{rev}). This increase in I_{rev} is an inherent tradeoff with a lowered barrier potential.

To address this increase in I_{rev}, applicants' new Schottky diode includes a trench structure 45, which results in the peak of the diodes electric field being pushed away from the Schottky barrier and reduced in magnitude. This reduces the barrier lowering with increased reverse bias voltage, which helps prevent reverse leakage current from increasing rapidly.

To emphasize these novel and unobvious advancements,

applicant's independent claim 1 has been amended to include the limitation that the diode includes "a trench structure on the surface of said n- layer, said diode experiencing a reverse leakage current under reverse bias, said trench structure reducing the amount of reverse leakage current."

Independent claim 15 was amended so that the diode's barrier potential is of a magnitude "that allows said diode to operate as a low forward voltage diode" with the diode "experiencing a reverse leakage current under reverse bias." It was also amended to include "a means for reducing the amount of said reverse leakage current."

Independent claim 43 was amended to include the limitation of the diode "operating as a low voltage diode." It further includes the limitation of "a trench structure on the surface of said semiconductor material, said diode experiencing a reverse leakage current under reverse bias, said trench structure reducing the amount of reverse leakage current."

Support for these amendments can be found in the claims as originally filed, in the specification on page 4, lines 6-14 and on page 12, line 15 to page 14, line 28, and in the figures as originally filed.

Mohammad et al. does not disclose, teach or suggest these limitation and applicants respectfully submit that these claims are allowable. The remaining claims that were rejected under this section depend from the allowable independent claims and are also allowable.

35 U.S.C 103(a)

The examiner rejected claims 6, 22 and 49 under 35 U.S.C. 103(a) as being unpatentable over Mohammad et al. as applied to claims 1-5, 7, 8, 14-21, 23, 24, 28 and 43-48 above, in view of Banari et all. The claims rejected under

this section depend from the allowable amended independent claims and are also allowable.

Applicants also added claims 52 through 57 to include dependent claims directed to the diode's low voltage operation and trench structure. Support for these claims can be found the same references to the application which support the amendments to the independent claims.

All of the claims in the application are now believed to be in proper form for allowance, and a Notice of Allowance is respectfully requested.

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

Claims

2. (Amended) A group III nitride based diode, comprising:

an n+ doped GaN layer;

an n- doped GaN layer on said n+ GaN layer;

a Schottky metal layer on said n- doped GaN layer having a work function, said n- GaN layer forming a junction with said Schottky metal, said junction having a barrier potential energy level that is dependent upon the work function of said Schottky metal; and

a trench structure on the surface of said n- layer, said diode experiencing a reverse leakage current under reverse bias, said trench structure reducing the amount of reverse leakage current.

2. (Amended) The diode of claim 1, wherein said barrier potential [varies directly with] depends on said Schottky metal work function.

3. (Amended) The diode of claim 1, wherein said n- doped GaN layer has an electron affinity, said barrier potential being [generally] approximately equal to said Schottky metal work function minus said electron affinity.

6. (Amended) The diode of claim 1, wherein said Schottky metal is one of the metals from the group comprising Ti, Cr, Nb, Sn, W, and Ta [and Ge].

16. (Amended) A diode, comprising:

a layer of highly doped gallium nitride semiconductor material [having an unpinned surface potential];

a layer of lower doped gallium nitride semiconductor material adjacent to the highly doped semiconductor material, said lower doped layer having an unpinned surface potential; and

a Schottky metal layer on said lower doped semiconductor material, said lower doped semiconductor material forming a junction with said Schottky metal having a barrier potential energy level that is dependent upon the type of Schottky metal, said barrier potential being of a magnitude that allows said diode to operate as a low forward voltage diode, said diode experiencing a reverse leakage current under reverse bias; and

a means for reducing the amount of said reverse leakage current.

19. (Amended) The diode of claim 15, wherein said Schottky metal contact has a work function, said barrier potential having an energy level that [varies directly with the] depends on said work function of said Schottky metal.

20. (Amended) The diode of claim [15] 18, further comprising a substrate adjacent to said n+ doped GaN layer, opposite said n- doped GaN layer.

22. (Amended) The diode of claim 15, wherein said Schottky metal is one of the metals in the group comprising Ti, Cr, Nb, Sn, W[, Ge] and Ta.

43. (Amended) A Schottky diode, comprising:

a semiconductor material having an unpinned surface potential; and

a Schottky metal having a work function and forming a junction with said semiconductor material that has a

barrier potential, the height of said barrier potential depending upon said work function, said diode operating as a low forward voltage diode; and

a trench structure on the surface of said semiconductor material, said diode experiencing a reverse leakage current under reverse bias, said trench structure reducing the amount of reverse leakage current.

47. (Amended) The diode of claim 43, wherein the height of said barrier potential [varies positively with the] which depends positively on said work function of said Schottky metal.

48. (Amended) The diode of claim 45, further comprising a substrate made of sapphire (Al_2O_3), silicon carbide (SiC) or silicon (Si), adjacent to [the] said n+ GaN layer, opposite said n- GaN layer.

49. (Amended) The diode of claim 43, wherein said Schottky metal is one of the metals in the group comprising Ti, Cr, Nb, Sn, W, Ta[, Ge] and other metals with similar work functions.